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CASE STUDY OF REINFORCED UNSTABLE SLOPE IN SOFT CLAY USING MICROPILE

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ABSTRACT: This paper presents a case study of unstable slope at a retention dam on the thick clay deposit. Dam was situated on a hill with purpose of capturing stormwater from houses area before releasing it to lower ground area. The problems faced due to the embankment has been constructed on thick soft clay deposit with higher groundwater table changing followed by crack and displacement at slope crest and needed to overcome immediately. Therefore, a series site investigations were conducted to be consists of soil profiles, slope geometric, and groundwater level. Soft clay was deposited below the embankment at the dam bench ranging from 7 - 13 meters thick at the northern side, so that the slope reinforcement was recommended by end bearing driven micropiles type with inclined configuration and head of micropiles to be fixed with slab concrete. At eastern side of the dam, infiltration of water from the dam to the embankment was prevented by using geomembrane / geosynthetic clay liners then woven geobag / geocontainer filling with gravels-sands and to be placed in front the ground slope. Due to bedrock is located at a deeper level of 25 m, water table below embankment is lowered in order to improve stability by floating sheet pile of span deck type with 10 meters length. Those cases are being to be constructed under these slope geometrics grand design. Furthermore, finite element analysis were performed to examine the effect of those method for improving slope stability of embankments. The results reveal that the ground reinforcement by micropile are able to increase the safety factor (SF) of the slope from 1.13 to 2.03 based on a traffic load of 20 kN/m^2.

Keywords: Micropiles, slope stability, soft clay, geosynthetic clay liner, safety factor.

INTRODUCTION

Soft soil is one of major constraints in infrastructure development in Indonesia. Slope stability on soft clay deposit is influenced by pore pressure and relation between shear strength and effective stress. The shear strength can be determined from pre-consolidation pressure and by using the shear strength the slope stability can be estimated (Lefebre, 1981). The analysis of slope stability in soft clay was developed by Gyllad et al (2011) and Huang et al (2012) by enhancing the model of strain softening of soft clay in FEM (Finite Element Method). While the analysis and modeling has been developed recently, the method of stabilizing slope in soft clay is also developed. The use of pile stabilizing slope was studied by Salem et al (2012), investigating the pile numbers and its relation to lime treatment of the slope and their effect on slope stability. They found that the lime treatment can reduce the pile numbers needed to stabilize slope in soft clay. Parametric study of stabilizing slope using piles was conducted by Kourkoulis et al. (2011). The fixity condition at the pile base varies from 0.7 to 1.5 times the thickness of soil, based on slenderness ratios and pile spacing. This study aims to investigate the effectiveness of pile to stabilize slope on dam bank. Case study was undertaken while FEM was done to analyze the influence of pile on slope stability.

CONDITIONS OF SLOPE FAILURE

We conducted a case study of residential house construction project in Alaya-Samarinda, the capital city of East Kalimantan Province. The project was hampered by a problem of unstable slope located at northern bank on small earthen dam which was built in order to capture stormwater from the surrounding areas of the houses (Fig. 1). The geometry of the dam is trapped with the bottom at elevation of +25 meters, and groundwater at +31.9 meters. It was found cracks on the northern bank of the dam and trees on the top of the bank obviously leaning. Moderate displacement was detected around the bank, closed the access road of houses.

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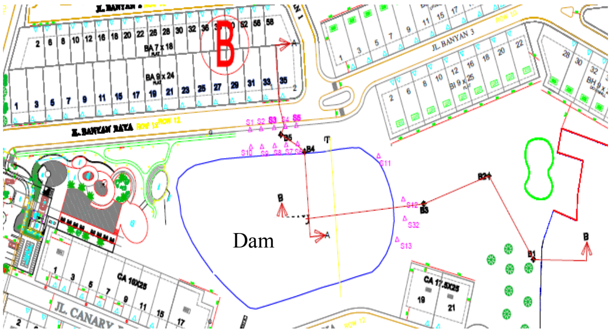

Fig. 1. Schematic view of residential houses and dam, and Cone Penetration Tests (CPTs).

Geotechnical Section Profiles

In order to characterize the subsurface of the slope, site investigation was conducted, consisting of 10 CPTs. It can be seen in Fig. 2 and 3, bedrock with q_c > 15 kN/m^2 was found at 10 to 17 meters below the surface. Soft clay is found with the thickness varies from 9 to 12 meters. As shown in Fig. 4 and 5, the bedrock depth toward northern of the dam.

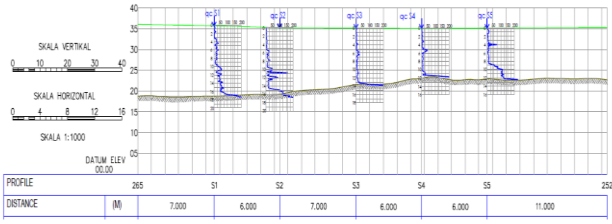

Fig. 2. Soil profiles of CPTs: S1, S2, S3, S4, and S5.

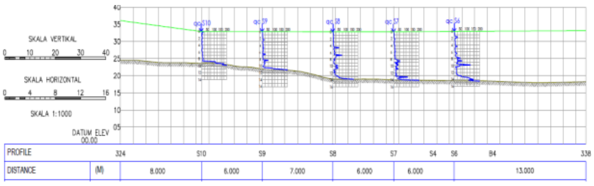

Fig. 3. Soil profiles of CPTs: S10, S9, S8, S7, and S6.

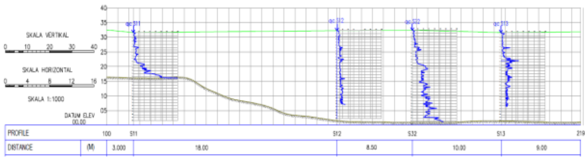

Fig. 4. Cross section A-A of the dam

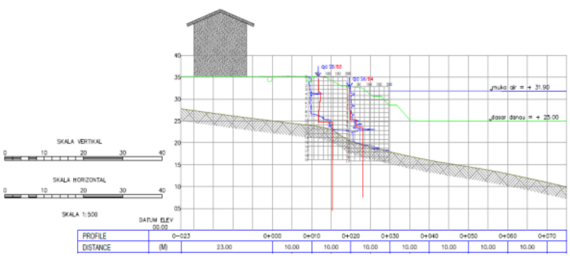

Fig. 5. Cross section B-B of the dam

Slope Benching and Micropile

To overcome instability, the slope was benched, becoming 3 - 4 traps. The top soil of the bank was excavated 4.3 meters with the slope gradient of 2V:2H (Fig. 6). The excavation is 2 meters from the road and 2 meters from the maximum water level at +31.9 meters. After the excavation, the ground was piled with concrete mini pile with dimension of 150×150 mm and 35 MPa compressive strength. This aims to reinforce the soft soil in the slope. It can be seen in Fig. 7, in a row, there is 4 piles with 10 meters length perpendicular and 2 piles with 12 meters length a bit inclined to the ground surface. The piles have to reach the bedrock and their tips penetrating until about 50 cm in the bedrock. At the head of the piles, wires was set with dimension of dia 6 mm and 150x150 mm^2 and then concreted with 20 MPa compressive strength. The fixation between head of piles was ensured by this concrete beam. Subdrain was installed in the slope by using PVC pipe with 4 inch diameter at every 5 meters along the slope, in order to prevent the stormwater infiltrating through the slope.

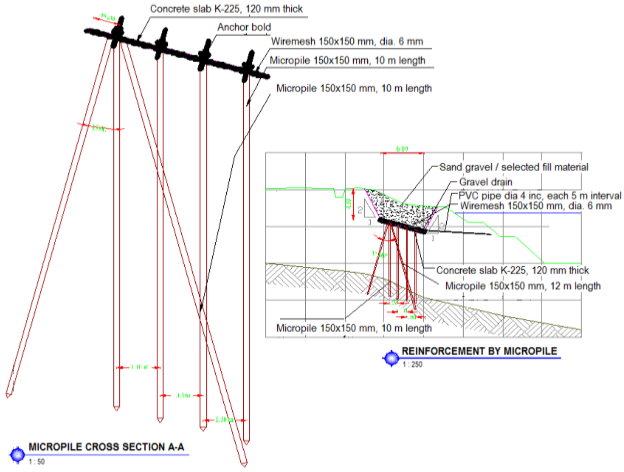

Fig. 6. Reinforcing by using micropile for northern slope in the dam.

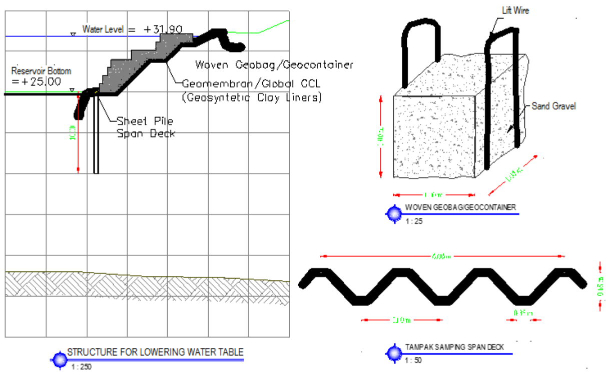

Fig. 7. Preventing water infiltration into the slope, at eastern slope in the dam

EMBANKMENT AT EASTERN SIDE OF DAM

At eastern side of the dam, 8 meters from dam bank, slope is located with 20% inclination. At this area, 4 CPTs were performed and it was found that bedrock at -32 meters from surface. Overall, existing slope is safe for potential sliding. However, infiltration of water from the dam to the embankment would be able to propagate crack due to the water level is high at 6.9 meters and quite closed to slope crest (8 meters). Therefore, in order to prevent infiltration, geomembrane / geosynthetic clay liners (GCL) are needed to be installed from the slope crest to slope toe at the dam base (Fig. 7). On the top of GCL, woven geobag / geocontainer should be set into consisting of 20 bags with dimension of 1×1×1 m^3 filled with gravels and sands. Due to bedrock is located at deeper lever (-23 meters from dam bottom), water can be infiltrated, therefore sheet pile of span deck must be piled into the ground with a length of 10 meters.

NUMERICAL ANALYSIS OF SLOPE STABILITY

Analysis and finite element modeling were undertaken to examine the effect of those two solutions on the stability of the slopes. The traffic load was set to be 20 kN/m^2. We employed PLAXIS 2D to model the slope and micropiles. The parameters used in the modeling were obtained from a number of laboratory tests including direct shear test, sieve analysis and atterberg test, and also correlation based on cone resistance values in CPT. The geometry of slope is based on the topography data of the slope. It was found that the finite element modeling can describe the difference between safety factor of slope without reinforcement and reinforcement. The micropile has been able to increase the safety factor of the slope from SF of 1.13 to be SF of 2.03 for traffic load of 20 kN/m^2 (Fig. 8 and 9).

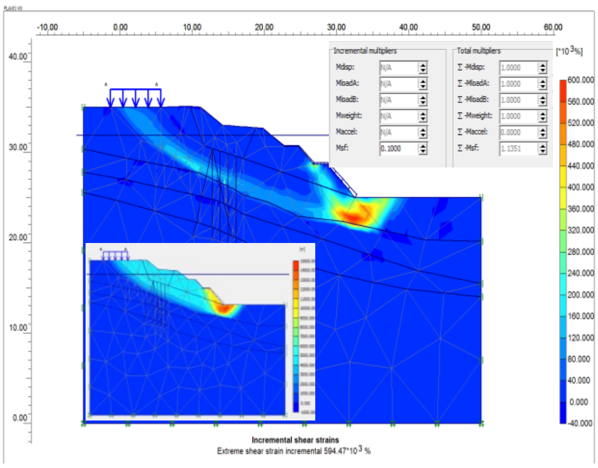

Fig. 8. Analysis of slope stability before reinforcement

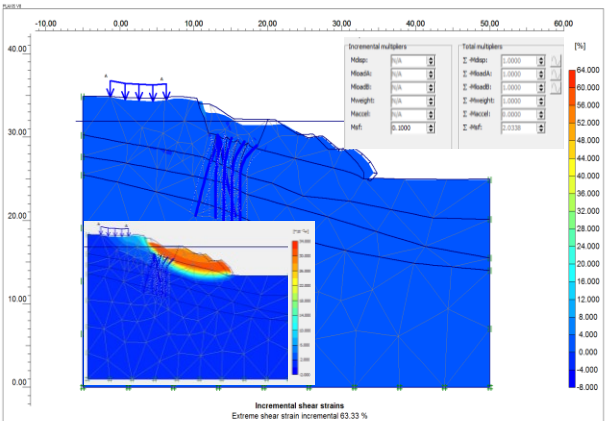

Fig. 9. Analysis of slope stability after reinforcement

CONCLUSIONS

The paper has analyzed to advance the knowledge and the effectiveness of the micropiles configuration over strategy reinforcement of soft soil slope failure in a residential house, the following aspects could be concluded:

1. Soft clay layers were identified to be deposited below the embankment at the dam bench ranging from 7 - 13 meters thick at the northern side, whereas the soft clay layers below the embankment in the eastern part of the retention dam are 25-30 meters thick.
2. Slope reinforcement of embankment in the northern part was designed by end bearing driven micropiles type, this could be able to reduce potential sliding of the slope. The configuration of micropiles combines perpendicular and inclined piles to the base of slope. The toe of micropiles must penetrate 50 cm under the bedrock.
3. For the eastern side of the dam, the use of geosynthetic clay liner (GCL) is adopted to prevent the seepage of dam water and reduce the potential cracks propagated along the slope. At the base of the slope, sheet pile with span deck can be installed to enhance the stability of the slope.
4. Finite element analysis were performed to examine the effect of slope grand design improvement on safety factor of embankments. The results reveal that ground reinforcement by micropile are able to increase the safety factor (SF) of the slope from 1.13 to 2.03 based on a traffic load of 20 kN/m^2.

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